Calculation of depleted wind resources near wind farms

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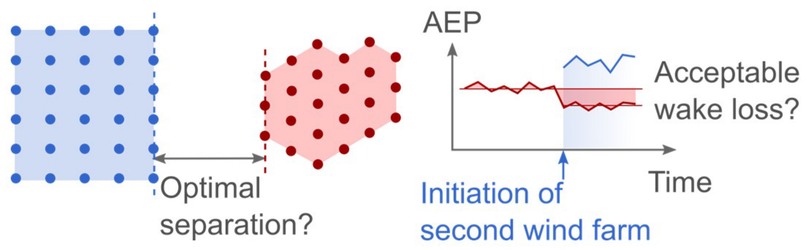
The problem

Wind energy planning authorities deals with questions like

- How much is the wind resource affected by existing wind farms?
- Will the production of existing wind farms decline after the construction of new ones?
- Do we need separating zones between wind farms and how wide should they be?

Maps of depleted wind resources near wind farms could be useful.



Two neighboring wind farms and their annual energy production

How to add wake effects to wind resource maps

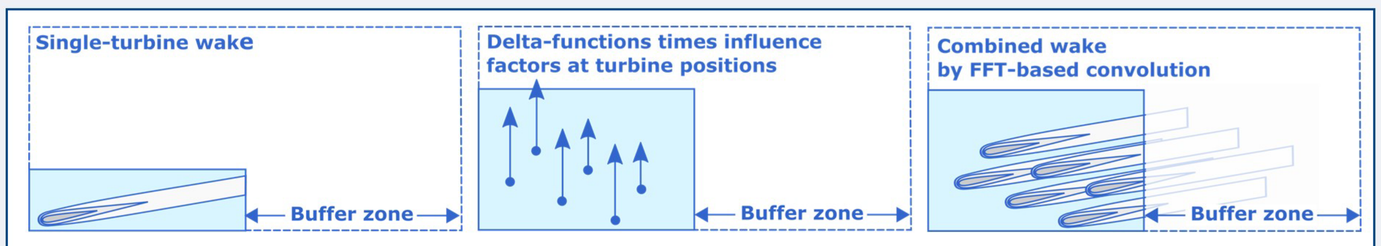
Traditional wind resource assessment programs like WAsP only present maps as undisturbed wind climates. We may, however, add wake effects to such maps and predict the depleted wind resource or effects of new wind farms.

The suggested procedure is to estimate turbine thrust by traditional methods and calculate the combined wind-farm wake by an FFT-based convolution. This is repeated for all wind conditions and wake-corrected wind resources are found for every grid node by statistical weighting with local wind climates. The calculation time for the combined wake depends on the number of distinct turbine types, but not on the number of turbines.

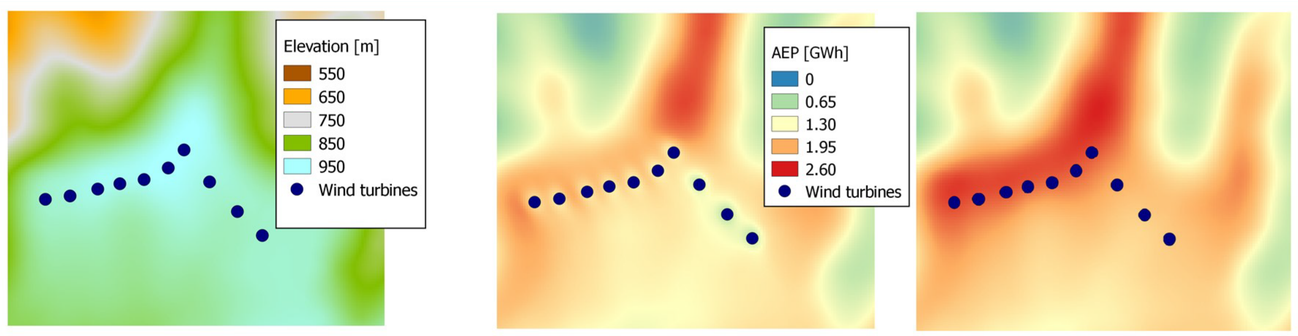
A simplifying assumption that wake-affected flow accelerates with nearly the same speedup factor as the free flow, allows us to extend the method to complex terrain.

The method is mainly intended for inter-farm wake effects, since grid resolution introduces a slight inaccuracy in individual turbine position and wake effects on nearby turbines.

The method will work for linear wake models like PARK and FUGA.



Method: 1) Add buffer zone, 2) FFT single-turbine wake and maps of influence factors, 3) multiply transformed maps, 4) inverse FFT to physical space and 5) remove buffer zone



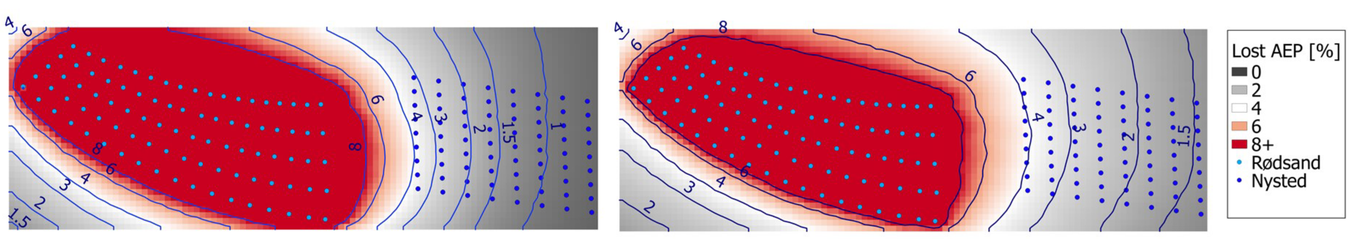
Wind farm in complex terrain: Terrain elevation and wind resource with or without wake effect.

Comparison of the PARK and FUGA wake models

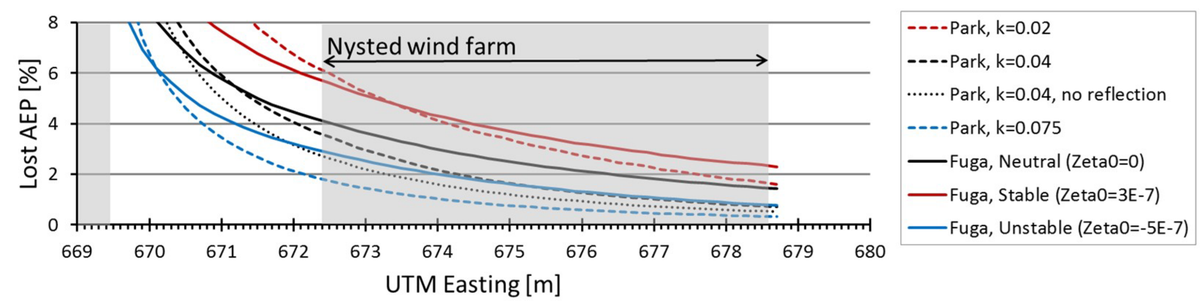
The top figure shows the depleted wind resource around the Rødsand wind farm as calculated by the PARK[1] and FUGA[2] wake models. The wind resource depletion decays with distance, and also depends on the predominantly downwind direction. The wake effect is still present at the neighboring Nysted wind farm.

The bottom figure shows a comparison of PARK and FUGA results along an East-West transect through the center of the neighboring Nysted wind farm. PARK results are shown for different wake decay factors and FUGA results are shown for variable atmospheric stability. Adjusting these model parameters has a similar effect and it is tempting to consider the PARK wake decay constant as a kind of stability parameter. It is however not possible to match the two models for all distances.

Adding wake effects from 90 turbines in Rødsand wind farm to the displayed 102x35 wind resource grid takes 9.6 s by the FFT-based algorithm and 286 s by direct computation. These calculation times increases to 14.0 s (FFT) and 515 s (direct) if we consider all 162 turbines of Nysted and Rødsand. For comparison it takes 7.8 s to calculate the wind resource grid without wake effects in WAsP 11.



Lost Annual Energy Production around Rødsand wind farm as predicted by 1) PARK with wake decay constant k=0.04 and 2) FUGA with neutral atmospheric stability



Comparison of lost AEP at the neighboring Nysted wind farm as predicted by PARK and FUGA

Conclusions

A new calculation method for maps of wake effects from multiple turbines is presented. It is sufficiently fast for calculating depleted wind resource near wind farms and wind farm clusters. The method has been used for a comparison of the PARK and FUGA wake models. As expected, FUGA is shown to be sensitive to atmospheric stability and PARK is sensitive to its empirical wake-decay factor. It is not possible to select a PARK wake-decay factor, which makes the two models match at all distances.

References

1. I. Katic, J. Højstrup and N. O. Jensen (1986). A Simple Model for Cluster Efficiency. In *Proceedings of EWEC'86, Rome, 7-9 October 1986. Eds. W. Palz and E. Sesto.,* Vol. I, p. 407-410.
2. S. Ott and M. Nielsen (2014). *Developments of the offshore wind turbine wake model Fuga*, Report E-0046, DTU Wind Energy, pp. 89